

## Patent Claims

1. A method for calibrating a tool center point (TCP)  
of tools (13) for industrial robots (8) comprising  
5 a calibration apparatus (1) that has at least two  
light barriers which are angled to one another  
with a vertex angle ( $\alpha$ ) greater than zero in each  
case and cross one another at a crossing point  
(R), exhibiting the steps of:  
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  - a) fixing DESIRED TCP positional coordinates of a  
DESIRED tool center point ( $TCP_{DESIRED}$ ) of the tool  
(13) with reference to a tool reference point (W)  
of an industrial robot (8), and to a TCP  
15 coordinate system referred to the tool center  
point (TCP), and
  - b) moving the tool (13) directly to the DESIRED  
tool center point with reference to the TCP  
20 coordinate system through the light barriers such  
that the tip of the tool (13) corresponding to the  
tool center point (TCP) interrupts the light  
barriers,
  - 25 characterized by
  - c) recording ACTUAL TCP positional coordinates  
upon the interruption of a respective light  
barrier,
  - 30 d) determining the differences between the DESIRED  
TCP positional coordinates for the interruption of  
the light barriers at a DESIRED tool center point  
( $TCP_{DESIRED}$ ) and the corresponding recorded ACTUAL  
35 TCP positional coordinates for the ACTUAL tool  
center point ( $TCP_{ACTUAL}$ ), and

5 e) calculating the deviation of the ACTUAL tool center point ( $TCP_{ACTUAL}$ ) from the DESIRED tool center point ( $TCP_{DESIRED}$ ) for the number of planes that is prescribed by the light barriers from the differences and the known position and vertex angles ( $\alpha$ ) for the light barriers.

10 2. The method as claimed in claim 1, characterized by correcting the TCP positional coordinates by the calculated deviation between the fixed ACTUAL TCP position coordinates by the calculated deviation of the ACTUAL tool center point ( $TCP_{ACTUAL}$ ) from the DESIRED tool center point ( $TCP_{DESIRED}$ ) for the planes of a coordinate system, on which the TCP  
15 positional coordinates are based.

20 3. The method as claimed in one of the preceding claims, characterized in that the DESIRED tool center point ( $TCP_{DESIRED}$ ) is fixed with the aid of the TCP positional coordinates in the case of which the tool tip corresponding to the tool center point (TCP) simultaneously interrupts all the light barriers at a common crossing point (R).

25 4. The method as claimed in one of the preceding claims, two light barriers being provided that cross one another at a vertex angle  $\alpha$  of  $90^\circ$  and define a first plane of a coordinate system, and with the first light barrier corresponding to a  
30 first axis (y), and the second light barrier corresponding to a second axis (z) of the coordinate system, characterized in that the deviation of the tool center point (TCP) for the first axis (y) is determined from the deviation, determined upon interruption of the first light  
35 barrier, of the ACTUAL tool center point ( $TCP_{ACTUAL}$ ) from the DESIRED tool center point ( $TCP_{DESIRED}$ ), and the deviation of the tool center point (TCP) for the second axis (z) is determined from the

deviation, determined upon interruption of the second light barrier, of the ACTUAL tool center point ( $TCP_{ACTUAL}$ ) from the DESIRED tool center point ( $TCP_{DESIRED}$ ).

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5. The method as claimed in one of the preceding claims, characterized by determining the ACTUAL TCP position coordinates as mean ACTUAL TCP positional coordinates between the instant of the interruption of a light barrier and the subsequent release of the light barrier.

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6. The method as claimed in claim 5, characterized by determining the tool diameter from the difference of the ACTUAL TCP positional coordinates determined at the instant of the interruption of a light barrier and the subsequent release of the light barrier.

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